Effects of climate model interdependency on the uncertainty quantification of extreme rainfall projections

Sunyer Pinya, Maria Antonia; Madsen, H.; Rosbjerg, Dan; Arnbjerg-Nielsen, Karsten

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Effects of climate model interdependency on the uncertainty quantification of extreme rainfall projections

M.A Sunyer [(1)], H. Madsen[(2)], D. Rosbjerg[(1)] and K. Arnbjerg-Nielsen[(1)]

[(1)] *DTU Environment, Miljøvej building 113, DK-2800 Kgs.Lyngby, Denmark (masu@env.dtu.dk)*

[(2)] *DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark*

Changes in rainfall extremes under climate change conditions are subject to numerous uncertainties. One of the most important uncertainties arises from the inherent uncertainty in climate models. In recent years, many efforts have been made in creating large multi-model ensembles of both Regional Climate Models (RCMs) and General Circulation Models (GCMs). These multi-model ensembles provide the information needed to estimate probabilistic climate change projections. Several probabilistic methods have been suggested. One common assumption in most of these methods is that the climate models are independent. The effects of this assumption on the uncertainty quantification of extreme rainfall projections are addressed in this study.

First, the interdependency of the 95% quantile of wet days in the ENSEMBLES RCMs is estimated. For this statistic and the region studied, the RCMs cannot be assumed independent. Then, a Bayesian approach that accounts for the interdependency of the climate models is developed in order to quantify the uncertainty. The results of the Bayesian approach show that the uncertainty is narrower when the models are considered independent. These results highlight the importance of accounting for the climate model interdependency when estimating the uncertainty of climate change projections.

Keywords: Interdependency, RCM, multi-model ensemble, uncertainty, extreme rainfall, Bayesian

INTERNATIONAL CONFERENCE

BOOK OF ABSTRACTS

Advanced methods for flood estimation in a variable & changing environment

GREECE
VOLOS
24 to 26
OCTOBER
2012

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF THESSALY

FLOODFREQ COST Action ES0901
European Procedures for Flood Frequency Estimation

BOOK OF ABSTRACTS

Advanced methods for flood estimation in a variable & changing environment

International Conference

Advanced Methods for Flood Estimation in a Variable and Changing Environment

ORGANISED BY: Laboratory of Hydrology and Aquatic Systems Analysis
Department of Civil Engineering
University of Thessaly

INTERNATIONAL SCIENTIFIC COMMITTEE

Kazimierz	BANASIK	Warsaw University, Poland
Sarka	BLASKOVA	T.G. Masaryk Water Research Institute, Czech Republic
Attilio	CASTELLARIN	University of Bologna, Italy
Thomas	KJELDSEN	Centre for Ecology & Hydrology, United Kingdom
Silvia	KOHNOVA	Slovak University of Technology, Slovakia
Michel	LANG	CEMAGREF, France
Deborah	LAWRENCE	Norwegian Water Resources and Energy Directorate, Norway
Athanasios	LOUKAS	University of Thessaly, Greece
Henrik	MADSEN	Danish Hydraulic Institute, Denmark
Bruno	MERZ	German Research Centre for Geosciences, Germany
Emmanuel	PAQUET	EDF, France
Witold	STRUPCZEWSKI	Institute of Geophysics PAS, Poland
Jan	SZOLGAY	Slovak University of Technology, Slovakia

CONFERENCE CHAIR

Athanasios	LOUKAS	University of Thessaly, Greece
Thomas	KJELDSEN	Centre for Ecology & Hydrology, United Kingdom

LOCAL ORGANIZING COMMITTEE

Prof. Nikitas MYLOPOULOS
Dr. Lampros VASILIADES
Mrs. Kalliope MICHAILIDOU-NOTARA
Mr. Marios SPILIOTOPOULOS
Mr. Pantelis SIDIROPOULOS
Mr. Georgios PAPAIOANNOU
Mr. Dimitris MEMTSAS
Mr. Athanasios GEORGIOU

PREFACE

Reliable estimates of expected extreme flood events are required for design and operation of vital infrastructure such as flood defenses, bridges and culverts, and also for more general flood risk management and planning, e.g. emergency planning, flood risk mapping, and for defining flood insurance premiums. In practice, this information is obtained through the use of flood frequency estimation techniques based on the principle of analyzing series of observed events to infer a probabilistic behavior, which is then extrapolated to provide estimates of the likely magnitude of future extreme events (e.g. the magnitude of the flood expected to be exceeded on average once every 100-year).

By nature, extreme flood events are seldom observed locally and hydrologists have little or no chance of gathering an adequate sample of catastrophes. This raises the question of how best to extrapolate to extreme events when no or only short series of recent events are available. Where methods do exists they are often simple and their ability to accurately predict the effect of environmental change (e.g. urbanization, land-use change, river training and climate change) is unknown. Also, the problem of consistent estimates of extreme floods for trans-boundary rivers is rarely considered.

The International Conference «***Advanced Methods for Flood Estimation in a Variable and Changing Environment***» has been organized as a Mid-term Conference of the *COST ES0901 Action "European Procedures for Flood Frequency Estimation – FloodFreq"* by the Laboratory of Hydrology and Aquatic Systems Analysis, Department of Civil Engineering, University of Thessaly in Volos, 24-26 October 2012. The conference was open to any researcher in the field. Its objectives were to act as a forum for the presentation of the progress made in the flood frequency estimation in the framework of the COST ES0901 Action, the research and practical applications of flood estimation in Europe and for discussion on these issues. The meeting focused on flood analysis using rainfall-runoff modeling, regional flood frequency analysis, flood risk, hydrometeorology and floods, flood frequency analysis in a changing environment, trend analysis of extreme events.

This publication includes the abstracts of the 34 presentations at the Conference and the keynote invited lectures. The two (2) keynote lectures were given by: ***Prof. Dr. Siegfried Demuth***, Chief, Hydrological Systems & Global Change Section, Division of Water Sciences, Natural Sciences Sector, UNESCO and ***Prof. George Tsakiris***, Centre for the Assessment of Natural Hazards & Proactive Planning and Laboratory of Reclamation Works & Water Resources Management School of Rural and Surveying Engineering, National Technical University of Athens.

TABLE OF CONTENTS

Advanced Methods for Flood Estimation in a Variable and Changing Environment
(Abstract Proceedings of the International Conference held at Volos, Greece, 26-28 October 2012)

THE INTERNATIONAL FLOOD INITIATIVE (IFI) – RECENT ACTIVITIES AND THE ROLE OF THE UN

Prof. Dr. Siegfried Demuth
Chief of Hydrological Systems and Global Change Section, Division of Water Sciences,
Natural Sciences Sector, UNESCO, Paris, France

Abstract: Flooding is the most taxing of water–related natural hazards to humans, material assets, cultural and ecological resources. Annually flooding affects about 520 million people and their livelihoods, claiming about 25000 lives worldwide. The annual cost of flooding is $60 billion to the world economy. The frequency of extreme flood events is changing due to urbanization, deforestation, potential climate change and rise in sea levels. International and national efforts to develop structural and non-structural practices to reduce flood risk have been made for years. These practices have been mainly applied through isolated sectoral approaches. There is a worldwide lack of integrated flood management approaches. New perspectives on flood management incorporating risk assessment need to be developed, taking into account economic and social aspect and ecological sustainability of vital system. At the same time, floods are naturally occurring phenomena, contributing to the biodiversity and sustainability of ecosystems and to many human activities. The International Flood Initiative (IFI) is a response to the increasing number of water-related disasters, deaths and widespread damage to goods and assets. IFI is a joint initiative of UNESCO-IHP, WMO, UNU, UN-ISDR and IAHS. The secretariat of IFI is based at in the International Centre for Water Hazard and Risk Management (ICHARM) hosted by the Public Works Research Institute in Tsukuba, Japan. The IFI, initiated in 2005 during the course of the UN International Decade for Action "Water for Life" (2005-2015), promotes the paradigm shift from flood management as a strategy of defence towards the trans-sectoral, trans-disciplinary approach of *integrated flood management* to maximize the long-term benefits of floods and to minimize the hardship, loss of life and damage to goods and assets that result from floods. It also follows guiding principles such as living with floods, equity for all stakeholders, empowered participation, inter-disciplinarity and trans-sectorality, international and regional cooperation. Therewith, the joint organizations try to cope with increasing flood frequency and damage as well as the worldwide lack of integrated flood management approaches. To achieve this, the initiative focuses on research, training, information networking, promoting good governance and providing technical assistance. The presentation gives an overview on the activities that the joint organizations carry out under the umbrella of IFI. The presented activities include numerous ongoing research projects on all aspects of integrated flood management, education and training projects, publications and assistance tools such as manuals or textbooks. Therewith it will be shown in which way the organizations associated in the IFI implement state-of-the-art flood management approaches internationally on a scientific basis.

Keywords: International Flood Initiative (IFI), floods, flood frequency, integrated flood management.

FLOOD RISK ASSESSMENT: CONCEPTS, MODELLING AND APPLICATIONS

Prof. George Tsakiris
Centre for the Assessment of Natural Hazards and Proactive Planning,
School of Rural and Surveying Engineering, National Technical University of Athens, Greece

Abstract: Floods are among the most disastrous natural hazards affecting large populations in many parts of the world, causing loss of human lives and wide spread damages to properties and infrastructure. The recent approach for assessing the severity of flood events is through the methodology «hazard-vulnerability-risk». This methodology is also adopted by the European Union by setting in force the flood directive 2007/60. In this overview study, the major concepts related to floods are explained, the steps for implementing the flood directive are presented and discussed, and some innovative aspects are proposed. Options of flood modelling, particularly caused by river overflow in mild terrain built areas are analysed. Emphasis is given to 1D and 2D flood models using numerical schemes which are based on shallow-water equations. Finally real world applications, demonstrating the above mentioned methodologies are presented. The limitations and uncertainties of flood modelling and the associated risk assessment are also discussed.

Keywords: floods, flood modelling, flood vulnerability, flood risk, flood risk assessment.

DESIGN FLOOD ESTIMATION FOR A SMALL CATCHMENT WITH THE USE OF SINGLE EVENT R-R MODEL

Kazimierz Banasik
Warsaw University of Life Scences – SGGW, Warsaw, Poland

Abstract: A procedure, called SEGMO (Sediment Graph Model) has been developed at the Department of Water Engineering of Warsaw University of Life Sciences – SGGW for predicting catchment response, as flood hydrograph and sedimentgraph, to heavy rainfall. The model consists of two parts; a hydrologic sub-model and sedimentology sub-model. The hydrologic submodel uses the Soil Conservation Service CN-method to estimate effective rainfall and the instantaneous unit hydrograph (IUH) procedure to transform the effective rainfall into a direct runoff hydrograph. The sedimentology submodel uses a form of the modified Universal Soil Loss Equation to estimate the amount of suspended sediment produced during the rainfall runoff event and the instantaneous unit sedimentgraph (IUSG) procedure to transform the produced sediment into a sedimentgraph. Only the first one i.e. hydrological submodel, called later rainfall-runoff model, will be used for catchment response as design flood to heavy rainfall of assumed probability of exidance. Parameters of the model, i.e. CN parameter of SCS method for effective rainfall computation and Nash model parameters of IUH for transformation of the effective rainfall into direct runoff, could be estimated on the base of existing guidelines and formulas or could be identified on the base of recorded rainfall-runoff events. The last one is applied, as recording of rainfall-runoff events in a small catchment of Zagożdżonka River at Płachty gauge (82 km^2), located in central Poland, have been carried out since 1980. Results of model application will be compared with results of FFA for this catchment.

Keywords: single event R-R modeling, SEGMO model, IUH, SCS-CN, Zagożdżonka River.

A MODELING SYSTEM FOR THE PREDICTION OF FLOOD RISK UNDER CHANGING LAND USE PRACTICES

Nektarios N. Kourgialas and George P. Karatzas
Department of Environmental Engineering, Technical University of Crete,
Polytechneioupolis, 73100 Chania, Greece
e-mail: nektarios.kourgialas@enveng.tuc.gr; karatzas@mred.tuc.gr

Abstract: A modeling system for the estimation of flood inundation is developed in this work.. This system comprises of two components: a) a modeling framework based on the hydrological model HSPF, and b) the hydraulic model MIKE 11. The proposed modeling system is used to evaluate different flood inundation scenarios. These scenarios represent changes in land uses, with emphasis on the riparian vegetation, which depends on seasonal variations and agricultural practices. The model results obtained for different land use scenarios can be employed to create flood protection measures for flood prone areas, especially in small river basins with short response times, ensuring public safety. Herein, emphasis is given to the seasonal variation of Manning's coefficient (n), an important parameter for the determination of the flood inundation in hydraulic modeling. Thus, this study highlights the significant impacts of land use and riparian vegetation changes on flood propagation modeling. Based on the obtained results, land use changes have a greater impact on the flood wave in the floodplain and dominant channel zones than in the low flow channel zone. The proposed methodology is applied to the downstream area of the Koiliaris River basin in Crete-Greece.

Keywords: ecohydraulics, flood inundation modeling, flood risk, land use changes, MIKE 11.

DESIGN HYDROGRAPH CALCULATION USING A DISTRIBUTED RAINFALL-RUNOFF MODEL FORCED BY A STOCHASTICH RAINFALL GENERATOR BASED ON COPULAS

A. Candela[1], G.T. Aronica[2], G. Brigandì[2] and M. Santoro[1]
[(1)]Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale e dei Materiali, Università di Palermo, ITALY, angela.candela@unipa.it
[(2)]Dipartimento di Ingegneria Civile University of Messina, Messina, ITALY

Abstract: In this paper a procedure to derive design hydrographs using a stochastic representation of rainfall forcing coupled with a distributed rainfall-runoff model is presented. The layout of the procedure can be resumed as follows: 1) single sub-hourly stochastic input of rainfall hyetograph to derive single synthetic rainfall events. Generated rainfall events are totally stochastic but with characteristics in terms of shape, duration and average intensity have to satisfy the parameters derived by statistical analyses of the available historic records. Generation of storm duration and rainfall intensity has been obtained via Frank Copula. As marginal laws for the two variables Weibull and Log-Normal has been chosen. In order to characterize the shape, dimensionless events are considered whose statistical characteristics has been modelled using Beta cumulative distribution; 2) rainfall-runoff modelling for estimating the hydrological response at the outlet of a watershed using a conceptual fully distributed model based on the Soil Conservation Service – Curve Number method as excess rainfall model and a distributed unit hydrograph with climatic dependencies for the flow routing. Travel time computation, based on the definition of a distributed unit hydrograph, has been performed, implementing a procedure using flow paths determined from a digital elevation model (DEM) and roughness parameters obtained from distributed geographical information. This procedure allows the taking into account of the differences, in terms of velocity, between the hillslopes and the stream system. The proposed procedure has been applied to two watersheds in Sicily, in order to establish the level of agreement between the estimated and recorded hydrographs, using as a tool to calculate the excess rainfall a simplified version of the probability distributed model. The procedure described above was applied to a Sicilian watersheds for which discharges at the outlet and sub-hourly rainfall at several raingauges, were available. Synthetic hydrographs were obtained starting from model variables distributions by simulating 1000 flood events using 1000 generated hyetographs. The application of this procedure showed how Monte Carlo simulation technique can reproduce the statistics of the simulated events with those of the measured data confirming the effectiveness and the reliability of the procedure.

Keywords: flood frequency estimation, copulas, distributed rainfall-runoff models, bivariate analysis, stochastic analysis.

Advanced Methods for Flood Estimation in a Variable and Changing Environment
(Abstract Proceedings of the International Conference held at Volos, Greece, 26-28 October 2012)

FOREST WATERSHED MODELLING USING GIS

D. Fotakis[1*], E. Sidiropoulos[1] and A. Loukas[2]
[(1)]Department of Rural and Surveying Engineering, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece
[(2)]Department of Civil Engineering, University of Thessaly, 38334 Volos, Greece
[(*)]Corresponding author: E-mail: jfotakis@topo.auth.gr,

Abstract: Watershed simulation software used for operational purposes must possess both dependability of results and flexibility in parameter selection and testing. The UBC watershed model (UBCWM) contains a wide spectrum of parameters expressing meteorological, geological, as well as ecological watershed characteristics. The hydrological model was coupled to the MapInfo GIS and the combined software created was named Watershed Mapper (WM). WM is endowed with several features permitting operational utilization. These include input data and basin geometry visualization, land use/cover and soil simulation, exporting of statistical results and thematic maps and interactive variation of disputed parameters. For the application of WM two hypothetical scenarios of forest fires were examined in a study watershed. Four major rainfall events were selected from 12-year daily precipitation data and the corresponding peak flows were estimated for the base line data and hypothetical scenarios. A significant increase was observed as an impact of forest fires on peak flows.

Keywords: forest watershed modelling, GIS, land cover change.

EXTREME EVENT ANALYSIS ON SPENCER CREEK WATERSHED

Ahmed Sadik[1] and Ioannis K. Tsanis[1,2]
[(1)]Department of Civil Engineering, McMaster University, Canada
[(2)]Department of Environmental Engineering, Technical University of Crete, Greece

Abstract: Climate change is expected to have a significant impact on the hydrologic cycle, resulting in changes on freshwater resources. The Intergovernmental Panel on Climate Change (IPCC) predicts that as a result, floods and prolonged droughts will take place at increasingly frequent periods. Data from the North American Regional Climate Change Assessment Program (NARCCAP) is used to study future trends and seasonality changes in precipitation and temperature and as input to hydrological models to study future trends in water resources. To achieve this goal, a set of Regional Climate Models (RCMs) at a spatial resolution of 50 km, driven by a set of atmosphere-ocean general circulation models (AOGCMs) under the SRES A2 emissions scenario for the 21st century, are used for the current period 1971-2000 and for the future period 2041-2070. The Spencer Creek watershed that extends over an area of 160 km^2 and is located in Southern Ontario is used as a case study. All future simulations show an increase in the average river discharge with seasonality shifts and changes in the return period of the extreme precipitation and runoff that can cause floods. Quantitative results of hydrological changes provide the data required to improve the existing policies on how to adapt to climate extremes.

Keywords: climate change, R-R modelling, extreme precipitation, floods.

RAINFALL RUNOFF MODELLING USING A HYBRID TECHNIQUE FOR POORLY GAUGED WATERSHEDS

Lampros Vasiliades and Athanasios Loukas
Department of Civil Engineering, University of Thessaly
Pedion Areos, 38334 Volos, Greece
e-mail: lvassil@uth.gr, Fax: +30 2421074169

Abstract: Meteorological and hydrological data are measured because they are necessary for understanding of the variables characterizing the hydrological processes in a watershed. The observed time series of meteorological data (usually, precipitation and temperature) at a number of stations and streamflow at the mouth of a watershed are used to model the hydrological response of the watershed and estimate the streamflow hydrograph. In ungauged basins, where meteorological data or streamflow, or both are not measured, hydrological models have to be developed without long time series of gauge records. In this study, a technique that couples a hydrological model with Artificial Neural Networks is developed to improve the streamflow simulation and estimation of peak flows for watersheds with limited streamflow data. The hybrid method is developed for modelling daily streamflow and subsequent estimation of flood frequency in poorly gauged watersheds and is based on the coupling of the University of British Columbia (UBC) watershed model for ungauged watersheds with artificial neural networks (ANNs) for use in watersheds with limited streamflow information. The UBC model is applied with a universal set of parameters for water allocation and flow routing, and precipitation gradients estimated from the available annual precipitation data as well as from regional information on the distribution of orographic precipitation. Then the simulated runoff components (i.e. rainfall fastflow, snowmelt fastflow, rainfall interflow, snowmelt interflow, upper zone groundwater, deep zone groundwater and glacial melt runoff) are used as an input to ANNs for streamflow simulation using limited streamflow measurements for the training period. The developed technique has been applied to five mountainous watersheds located in three geographical areas of the world with largely varying climatic, physiographic and hydrological characteristics. The results showed that the regional application of UBC model satisfactorily simulates the observed hydrograph assuming that the basins are ungauged. When limited streamflow measurements are available, the simulation of the runoff and the estimation of flood frequency are highly improved using the hybrid method.

Keywords: UBC watershed model, neural networks, rainfall-runoff modelling, model coupling, poorly gauged watersheds.

EXTRAFLO PROJECT: COMPARISON OF SEVERAL STATISTICAL FRAMEWORKS (LOCAL, REGIONAL, LOCAL-REGIONAL) FOR FLOOD QUANTILE ESTIMATION

Michel Lang[1], Benjamin Renard[1], Krzysztof Kochanek[1], Patrick Arnaud[2] and Yoann Aubert[2]
(1) Irstea, Hydrology-Hydraulics research unit, 3 bis quai Chauveau, 69336 Lyon cedex 09, France
(2) Irstea,Hydraulics structure and Hydrology research unit, 3275 Route de Cézanne - CS 40061 - 13182 Aix-en-Provence Cedex 5, France

Abstract: The objective of the ExtraFlo project (2009-2012), which is funded by the French National Agency of Research (ANR), is to carry out an intercomparison of the main methods used in France for estimating extreme values of rainfall and floods. A large dataset has been collected, with several thousand rainfall and discharge data series. It has been split into calibration and validation subsets. This paper will present a comparison of three statistical frameworks for flood frequency analysis: 1/ local approach, fitting a distribution to the maximum values of a single data series; 2/ local-regional approach, fitting a regional scaled distribution and estimating index flood values from the local series; 3/ regional approach, using a regional scaled distribution and a regression to estimate index flood values without local data series. Both the Gumbel and the Generalized Extreme Value (GEV) distributions are used in the comparison. Results highlight that both local and regional approaches yield severe predictive failures in validation mode. These approaches are outperformed by local-regional approaches, which yield much more reliable predictions. Moreover, using local-regional approaches allows distinguishing regions where the GEV/Gumbel distributions yield contrasted predictive performances, therefore helping in the selection of the relevant distribution.

Keywords: flood frequency analysis, regional distribution, stability, reliability, split sample.

FLOOD DESIGN *RECIPES* VS. *REALITY*: CAN PREDICTIONS FOR UNGAUGED BASINS BE TRUSTED? – A PERSPECTIVE FROM GREECE

Andreas Efstratiadis[1], Antonis Koussis[2], Demetris Koutsoyiannis[1], Nikos Mamassis[1] and Spyros Lykoudis[2]
[(1)]Department of Water Resources and Environmental Engineering, National Technical University of Athens, Heroon Polytechneiou 5, GR-157 80, Zographou, Greece
[(2)]Institute of Environmental Research and Sustainable Development, National Observatory of Athens, Ioannou Metaxa & Vasileos Pavlou, GR-152 36, Palaia Penteli, Greece

Abstract: As a result of its highly fragmented geomorphology, Greece comprises hundreds of small- and medium-scale steep hydrological basins of usually ephemeral regime. Typically, their drainage area does not exceed few hundreds of km^2, while the vast majority of them lacks of measuring infrastructures. For this reason, and despite the great scientific and technological advances in flood hydrology, the everyday engineering practices still follow simplistic rules-of-thumb and semi-empirical approaches, which are feasible and easy to implement in ungauged areas. In general, these "recipes" have been developed many decades ago, based on field data from few experimental catchments abroad. However, none of them has ever been validated against the peculiarities of the hydroclimatic regime and the geomorphological conditions of Greece. This has an obvious impact on the quality and reliability of hydrological studies, and, consequently, the safety and cost of the related flood-protection works. In order to provide a consistent design framework and ensure realistic predictions of the flood risk in ungauged basins (which is key issue of the 2007/60/EU Directive), it is imperative to revise the rather outdated engineering practices, by incorporating methodologies that are adapted to local peculiarities. In particular, the collection of reliable hydrological data is essential for evaluating and verifying the existing "recipes" and updating the design criteria. In this context, we are elaborating a research program titled "Deukalion", in which we already have developed a fully-equipped monitoring network, extending over four pilot river basins. Preliminary outcomes, based on historical flood data from Cyprus and Greece, indicate that a substantial revision is required within multiple aspects of the flood modeling procedure.

Keywords: flood engineering, Deukalion project, experimental basins.

Advanced Methods for Flood Estimation in a Variable and Changing Environment
(Abstract Proceedings of the International Conference held at Volos, Greece, 26-28 October 2012)

REGIONAL FLOOD HYDROLOGY OF A SEMI-ARID REGION

Luis Mediero[1] and Thomas Kjeldsen[2]
[(1)] Technical University of Madrid, Department of Civil Engineering: Hydraulic and Energy, Madrid, Spain
[(2)] Centre for Ecology and Hydrology, Wallingford, UK

Abstract: Regional flood hydrology suggests that the hydrological information content should be expanded at the site of interest to improve flood frequency estimates, through temporal, spatial and causal expansion. Spatial expansion is recommended to estimate flood frequency at ungauged sites by the use of a hydrological regression model, which links a hydrological variable to a set of catchment descriptors. An exploratory analysis to explain differences in flood processes among catchments and regions by catchment descriptors is carried out. The generalized least squares technique was selected. Correlation of modelling errors between catchments was included in the covariance matrix of the regression errors. The analysis has been applied to a semi-arid basin located in Spain, the Ebro River basin with an area of 86,000 km^2. Differences in flood characteristics among catchments were explained by the aridity index, to take differences in soil moisture content at the beginning of the flood event into account, and the slope of the flow duration curve, to consider the influence of subsurface flows on controlling the runoff regime. Both regional clustering of the correlation between regression residuals and catchment descriptors and the variance of residuals were reduced.

Keywords: regional floods, catchment descriptors, Ebro river basin.

THE METHODOLOGY FOR FLOOD FREQUENCY ESTIMATIONS IN SMALL CATCHMENTS

Vaclav David and Tereza Davidová
Department of Irrigation, Drainage and Landscape Engineering, Faculty of Civil Engineering, Czech Technical University in Prague, Thakurova 7, 166 29 Prague 6 – Dejvice, Czech Republic,
e-mail: vaclav.david@fsv.cvut.cz, tereza.davidova@fsv.cvut.cz

Abstract: It is usually quite difficult to estimate flood frequency parameters in small catchments due to lack of measured discharge data in the Czech Republic which is similar situation as in other countries. This problem is usually solved by hydrologic modelling when there is a reason not to use the data provided by the Czech hydrometeorological institute which are quite costly and have a very poor level of accuracy. Another way could be to use some simple method which would provide sufficient estimates of flood frequency based on the available spatial data. Such method is being developed at the Department of Irrigation, Drainage and Landscape Engineering. The methodology is being developed with involvement of all important factors affecting flood formation in small catchments. It has a shape of product of mathematical functions of selected catchment descriptors as well as of precipitation total with given return period. The relationship between catchment descriptors and flood characteristics has been a subject of recent research. The results will be then used to define shapes of mentioned mathematical functions. Finally, the dataset of catchments with known flood frequencies as well as with known values of its descriptors will be used to derive parameters of the basic equation for the flood frequency calculation. This paper presents the results of the investigation of the relationship between catchment descriptors and flood characteristics as well as the shape of the methodology. The methodology of catchment shape descriptors calculation including the data used for this purpose is also involved.

Keywords: GIS, catchment descriptor, small catchment, multiparametric optimization.

TRENDS IN ANNUAL AND SEASONAL MAXIMA OF DAILY RAINFALL AND PEAK RIVER FLOW

Ilaria Prosdocimi*, Thomas R. Kjeldsen and Cecilia Svensson
Centre for Ecology & Hydrology, Maclean Building, Benson Lane, Crowmarsh Gifford, OX10 8BB –UK
*email: ilapro@ceh.ac.uk

Abstract: With the public perception that climate has been changing in the last decades, more and more doubts are raised regarding the validity of the assumption of stationarity for hydrological processes. In this work we explore, in a descriptive and preliminary way, trends for annual and seasonal maxima in daily rainfall and peak river flow, applying a linear regression model allowing the mean of the distribution to vary with time. Over a longer period (50 years), trends do not seem to be significant, while there is indication of some slight, although not spatially coherent, trends in shorter series (20 years). Particularly in summer, there seem to be little concordance in the direction of trends for rainfall and flow, suggesting that other factors, such as evaporation, land use change, water management practices, etc, affect the river flows. Another concern is whether or not the standard linear regression can cope with extreme records. We discuss these issues and look into possible alternative approaches.

Keywords: annual and seasonal maxima, daily rainfall, peak flow, stationarity, trend analysis.

CORRELATION BETWEEN MORPHOLOGICAL PARAMETERS AND STREAM FLOW DATA IN SELECTED TORRENT OF SAMOS ISLAND.

Panagiotis Mourtzios[1] and Aris Psilovikos[2]
[(1)]Department of Agriculture, Crop Production and Rural Environment, School of Agricultural Sciences, University of Thessaly, Fytoko st., N. Ionia Magnisias, 38446, GREECE. (panajotis@hotmail.com)
[(2)]Department of Agriculture Ichthyology and Aquatic Environment, School of Agricultural Sciences, University of Thessaly, Fytoko st., N. Ionia Magnisias, 38446, GREECE. (psiloviko@uth.gr)

Abstract: The interrelations between specific morphometric and hydrologic parameters were examined for selected river basins in torrents of Samos Island. The morphometric parameters that were examined and calculated are: a) Total Length of Channels [ΣL], b) Area [A], c) Perimeter [P], d) Drainage Density [D], e) Channel Frequency [F], f) Relief Ratio [Rh], g) Hypsometric Integral [Hi], h) Circularity [Cu] and i) Elongation Ratio [Er] of the 3rd order catchments. These morphometric parameters were correlated with two very important hydrologic parameters during the flooding episodes: a) Flood Discharge [Q] and b) Time of Concentration [Tc] for each one of the river basins. The evaluation of the morphometric parameters in specific river basins and their correlation with the hydrologic ones, is a very important step to estimate the flooding hazards in vulnerable areas with the contribution of geomorphology.

Keywords: geomorphology, flood event, morphometric and hydrologic parameters, time of concentration, flood discharge.

DERIVATION OF FLOOD-RISK MAPS FOR THE WARSAW REACH OF THE RIVER VISTULA

Renata Romanowicz[1], Adam Kiczko[2] and Marzena Osuch[1]
[(1)]Institute of Geophysics Polish Academy of Sciences, Księcia Janusza 64, 01-452 Warszawa, Poland,
e-mail: romanowicz@igf.edu.pl
[(2)]Warsaw Agricultural University, Nowoursynowska 166, 02-787 Warszawa, Poland

Abstract: Derivation of flood risk maps requires estimation of maximum inundation extent for a flood with assumed probability of return (so called 1-in-100 or 1-in-500 year flood). The results of numerical simulation of flood wave propagation are used to overcome the lack of relevant observations. In practice, deterministic 1-D models are used for flow routing, giving a simplified image of a flood wave propagation process. The aim of this work is the analysis of an influence of uncertainty of observations and modelling errors on flood inundation mapping and a quantitative comparison with deterministic flood extent maps derived using a single realisation of a flow routing model. We derive a relationship between the inundation extent area and discharge for a short, low-land river reach and apply it as a measure of small-scale nonlinearity of flow transformation processes. The analysis is performed for a steady state solution of the 1-D flow routing model HECRAS. For the comparison purpose, we assume that deterministic estimates of water levels along the river reach, obtained for a flood wave with assumed probability of return, have the probability of occurrence equal to 0.5. In order to estimate the uncertainty of simulated water levels in the river we apply the informal Bayesian uncertainty estimation procedure. Apart from the uncertainty related to the model structure and its parameters, also the uncertainty of the estimated flood wave with a specified probability of return is taken into account. We apply Flood Frequency Analysis (FFA) to observed annual maximum discharges and derive theoretical distribution using the Maximum Likelihood approach. The uncertainty related to the design flood is estimated based on the theoretical distribution uncertainty limits. In order to derive the uncertainty of inundation extent conditioned on the design flood wave, the probabilities related to the design wave and flow model uncertainties are integrated, taking into account the dependence of model roughness coefficients on flow. The methods are illustrated using the Warsaw reach of the River Vistula as a case study. The results indicate that the uncertainties have a substantial influence on the flood risk assessment.

Keywords: map of probabilities of inundation, Bayesian uncertainty estimation, flow routing model HECRAS, maximum annual flows.

Advanced Methods for Flood Estimation in a Variable and Changing Environment
(Abstract Proceedings of the International Conference held at Volos, Greece, 26-28 October 2012)

FLOOD RISK FOR EMBANKED RIVERS

Ewa Bogdanowicz[1], Witold G. Strupczewski[2], Krzysztof Kochanek[2] and Iwona Markiewicz[2]
[(1)]Institute of Meteorology and Water Management. Podlesna 61; 01-673 Warsaw, Poland
(ewa.bogdanowicz@imgw.pl)
[(2)]Institute of Geophysics, Polish Academy of Sciences. Ksiecia Janusza 64, 01-452 Warsaw, Poland
(wgs@igf.edu.pl, kochanek@igf.edu.pl, iwonamar@igf.edu.pl)

Abstract: The flood frequency analysis (FFA) concentrates on peak flows of flood hydrographs. However, floods that last years devastated large parts of Poland lead us to revision of the views on the assessment of flood risk in Poland. It turned out that it is the prolonged exposure to high water on levees that causes floods, not only the water overflowing the levee crest. This is because, the levees are weakened by water and their disruption occurs when it seems that the danger is over, i.e. after passing culmination. Two main causes of inundation of embanked rivers, namely over-crest flow and wash out of the levees, are combined to assess the total risk of inundation. Therefore the risk of inundation is the total of risk of exceeding embankment crest by flood peak and risk of washout of levees. Hence, while modeling the flood events in addition to the maximum flow one should consider also the duration of high water in a river channel. Analysis of the frequency of annual peak flows based on annual maxima and peaks over threshold is the subject of countless publications. Therefore we will here mainly modeling the duration of high water levels. In the paper the two-component model of flood waves, 'duration of flooding-discharge-probability of non-exceedance' (DqF), with the methodology of its parameters estimation for stationary and non-stationary case was developed as a completion to the classical FFA and nonstationary FFA methods. The results of theoretical research were supplemented by a practical example of the model application to the series for daily flow in the Vistula River in Szczucin. Regardless promising results, this method is still in its infancy despite its great cognitive potential and practical importance. Therefore, we would like to point to the usefulness and necessity of the DqF models to the one-dimensional analysis of the peak flood hydrographs and to flood risk analysis. This approach constitutes a new direction in FFA for embanked rivers.

Keywords: inundation, embanked rivers, flood persistence, annual flow peaks, levee leakage.

LOOKING FOR A MORE COMPREHENSIVE APPROACH

J. Javier Diez
Technical University of Madrid.
FP7 SMARTeST Project. E-mail: jjdiez@caminos.upm.es

Abstract: The necessity/convenience for improving accuracy in determining the flood frequency widely accepted in old fields of risk management and not only among hydrologists, and is also increasingly deepened in relationship with the statement of different thresholds related to the respective management systems. It is occurring independently that both Scientific and Management Communities fully accept the necessity of living with determined levels of flood risk, looking for an adequate Risk (Resilience) Management (*SMARTeST*:"Integrated flood -resilience- risk management policy*"). Most of the approaches for "Advancing Methods" improving concentrate on the statistical ways, leaving or not for it their background or hypothesis of Stationariety. This is in fact a question already clear for most of them: Climate is not a Stationary process but some of its phenomena/parameters may be so considered in function of the lag time taken for the analysis, and depending on their particular nature, therefore the necessity of deeper and wider research about it (*SMARTeST*: "Communication between multi-disciplinary partners" recommendation)*. But the "Field Work" (*SMARTeST* recommendation)* is much more necessary than numerical approaches, and in this sense the historical approach is being increasingly adopted (*SMARTeST*:* "*Historical research -learning from the pass-" recommendation*), even by statistics when looking for the possibility of enlarging through it their temporal series, mainly looking for the assessment of a better link between Climate and Hydrology and, in within it, between the hydrologic parameters and the wider and more controlled land use conditions (*SMARTeST*:* "*Deeper and more multi-disciplinary climatic/hydrologic/subsidence research" policy)* . But it might be afraid a relatively scarce attention to the links between Hydrologic conditions and other parts of the Double Thermal Machine Circuit which determine the Climate, in one of whose cycles the hydrological processes are part of (*SMARTeST**: "*Consider full array of flood events" policy).* This document and presentation try to evidence both the meaning of those links and the necessity of stronger historic research on the flood events; the last looking at events as "story telling of case study", in which not only pluvial and fluvial parameters necessarily have to be assessed but other (upon them and wider) atmospheric and maritime (facing to the basin) as well (*SMARTeST**: "*Complete flood risk mapping" recommendation).*

Keywords: flood, risk management, resilience, stationarity, climate, thermal machine, multidisciplinearity, historical research, basin and coast, field work.

---

*SMARTeST Project Final Conference Highlights. Athens September, 27-28th 2012

FLOOD RESILIENCE TECHNOLOGY AS A TOOL OF ADAPTATION OF THE BUILT ENVIRONMENT TO INCREASED FLOOD HAZARD AND RISK

Antonis D. Toumazis
Dion. Toumazis & Associates, 4 Romanos Street, 1070 Nicosia, Cyprus

Abstract: Flood Resilience (FRe) Technology is a tool that reduces the risk of flooding in built up areas and especially at a local (property) level. This technology is compatible with the slogan "Living with the Floods", whereby the increased flood hazard is recognized and the built environment is adapted to this new environment. Many products are available in the market targeted and satisfying various applications. A design tool has been developed which enables consulting engineers to design flood barriers for particular projects, taking into account the flood loading (when the barriers are open), traffic loading (when the barriers are closed), durability requirements, mounting and demounting method, pavement material restrictions, water-tightness, budget allowance. Flood Resilience (FRe) technology is a promising tool for areas exposed to flood hazards (fluvial, pluvial, coastal etc) and with increased risk of damage (loss of life, property, disruption of operations).

Keywords: living with the floods, flood barriers, flood adaptation measures, flood resilience technology.

LINKING FLOOD HAZARD AND CLIMATE VARIABILITY – A METHOD FOR FUTURE FLOOD HAZARD PROJECTIONS

H. Apel, Nguyen Viet Dung and José Miguel Delgado
GFZ German Research Centre for Geoscience, Section 5.4 Hydrology, Potsdam, Germany

Abstract: Flood hazard analysis is an indispensable input for flood risk assessment. An essential part is the determination of probabilities of occurrence of floods of different magnitudes. The statistical methods applied for the determination, typically flood frequency analysis, are mostly based on the stationary assumption. However, this assumption does not hold for most of the observed discharge time series in general, and in particular not for future climate conditions. It is now commonly agreed that climate change leads to changing flood hazards. Therefore, this study aims at developing a novel approach for flood hazard mapping considering the change in climate variability with the Mekong delta as an example. We explicitly take non-stationarity in the annual maximum flood peak discharge (AMS) time series into account, because tests have shown that the observed time series are trend-free, i.e. not stationary. We further analyzed the dependency of the statistical distributions of AMS to the variance in monsoon indexes, a reliable proxy for flood intensity in the Mekong Delta, avoiding time consuming and error prone downscaling of GCM results and hydrological modelling to estimate climate change effects on flood generation. Future development of the flood intensity and frequency was consequently estimated by the identified non-stationarity in the extreme value statistics, the dependency of the frequency distributions to monsoon intensity, and the monsoon variability simulated by a number of different GCM's. The selected GMC's were tested for their skill to simulate the observed variability of the monsoon, and a criterion was developed to exclude non-skillful GCM's from the analysis. The changes in the frequency of flood peak were mapped into probabilistic inundation maps by driving a large scale hydrodynamic model for the Mekong delta in a Monte Carlo framework considering uncertainties in the model structure and parameterization. A comparison of these maps for the projection years 2030 and 2050 with the reference year 2010 illustrates the changes in flood hazard in terms of maximum inundation depths and extends spatially explicit for the whole delta.

Keywords: flood hazard, uncertainty, climate change, non-stationarity, flood frequency analysis, inundation modelling, Mekong Delta.

Advanced Methods for Flood Estimation in a Variable and Changing Environment
(Abstract Proceedings of the International Conference held at Volos, Greece, 26-28 October 2012)

COMPARISON OF PRECIPITATION/RUNOFF METHODS FOR DESIGN FLOOD ESTIMATION IN TWO NORWEGIAN CATCHMENTS

Deborah. Lawrence[1], Emmanuel Paquet[2] and Anne Fleig[1]
[(1)]Norwegian Water Resources and Energy Directorate (NVE), Oslo, Norway
[(2)]Électricité de France (EDF), Grenoble, France

Abstract: Alternative modelling methods for estimating the 1000-year design flood have been applied to the Atnasjø and Krinsvatn catchments in Norway as part of the intercomparison studies of COST FloodFreq WG3. The methods include a) a simple, event-based, three-parameter model for estimating peak discharge in response to an estimated 1000-year design precipitation (PQRUT); 2) a calibrated hydrological model with the 1000-year design precipitation sequence iterated through a simulation period (HBV-Design Flood); and 3) a stochastic, semi-continuous, rainfall-runoff simulation system with precipitation probabilistic model conditioned by regional weather types (SCHADEX). These three methods represent current operational practise in Norway, Finland/Sweden, and France, respectively. In addition to the three modelling methods, statistical flood frequency analysis based on observed discharge series has also been applied to enable a wider comparison of the estimates for the 1000-year flood. The PQRUT methodology requires an independent assessment of the snowmelt contribution to runoff during the event, and the initial catchment conditions are generally assumed to be at full saturation. A design precipitation sequence with a return period of 1000 years is used, and it is assumed to produce the corresponding 1000-year flood. These assumptions produce conservative estimates, which can significantly exceed estimates based on statistical flood frequency analysis. Some of these limitations are overcome using the HBV-Design Flood method, where the design precipitation sequence is iteratively moved through a simulated period of record based on a hydrological model, such that a range of catchment saturation and snowmelt conditions are sampled. A single input precipitation sequence is, however, used, such that only one, rather than a range of relevant extreme precipitation events is considered. Consequently, it is not possible to meaningfully quantify the return period of this design event, nor the distribution of events it represents. The SCHADEX methodology also uses a hydrological simulation to describe the continuously varying state of the catchment, and this is coupled with an event-based rainfall generator for introducing 'centred rainy events' within a stochastic simulation framework. An exhaustive range of possible streamflow responses to extreme rainfall events is thereby produced, given the sampled range of catchment conditions. The return interval of a combined rainfall/snowmelt event, as well as part of the uncertainty in the design flood estimation can therefore be estimated. The probabilistic rainfall model which drives the event-based rainfall generator is, of course, a critical component of the SCHADEX methodology. For the application to the Norwegian catchments presented here, it was necessary to develop a weather patterns classification based on extreme rainfall for Norway for use in building a distribution of weather patterns. This weather pattern classification was developed as part of a COST FloodFreq STSM (Fleig, 2011) between NVE and EDF. Comparison of the estimated 1000-year flood based on the various methods indicates that for Atnasjø, characterised by a snowmelt-dominated flood regime, the SCHADEX method, gives a somewhat lower when compared with the other simulation methods, as expected. The SCHADEX estimate is, however, similar to the 1000-year flood estimated by statistical methods based on the observed annual maximum series. At Krinsvatn, characterised by a rainfall-dominated flood regime with some occasional snowmelt, the SCHADEX method gives a value which is much closer to the statistical FFA and is higher than the other two methods, which are undermined by unrealistically low values for the design precipitation. The comparison demonstrates the value to be gained by using alternative methods for design flood estimate, where possible. It is also concluded that the SCHADEX method represents a suitable strategy for estimating return periods of flood events caused by a combination of extreme rainfall and snowmelt, and has the distinct advantage of providing a distribution of possible flood events which can potentially be used in a risk-based analysis. Further development of the SCHADEX methodology for possible use in Norway requires, however, that strategies for applications to ungauged catchments also be developed. Such strategies are currently under investigation in a Ph.D. project currently underway at EDF.

Keywords: flood frequency analysis, SCADEX methodology, regional methods, ungauged catchments.

INTENSE SUMMER STORMS IN SWITZERLAND: IDENTIFICATION ON THE BASIS OF LIGHTNING AND A TREND ANALYSIS

L. Gaal[1,2], P. Molnar[1] and J. Szolgay[2]
[(1)]ETH Zurich, Institute of Environmental Engineering, Zurich, Switzerland
[(2)]Slovak University of Technology, Faculty of Civil Engineering, Bratislava, Slovakia

Abstract: In this study we focus on the identification of precipitation events with convective character on the basis of local high resolution data (lightning strikes, precipitation), and not taking into consideration any information on the character of precipitation on the basis of distant meteorological measurements (radars, satellites). A differentiation between the two basic types of precipitation is of great importance in hydrological modeling and engineering practice: intensive convective events (thunderstorms) that usually result in devastating flash floods and soil erosion are of a particular interest in urban hydrology, while the stratiform precipitation events that lead to slow saturation of catchments and cause widespread flooding are studied in larger scale hydrology. The study is focused on Switzerland and is based on precipitation records that are available from the SwissMetNet (MeteoSwiss) network. These stations measure precipitation depth (mean intensity) at a 10-min time step with a heated tipping-bucket gauge with tip resolution 0.1 mm. The records are available at 58 stations that cover altitudes ranging from 200 up to 3300 m a.s.l. over the period 1981-2009 (29 years). Additionally, the same stations also measure the number of lightning strikes within a range of 30 km from the station, and these data are available for the period 1987-2009 (23 years). From this database, independent rainfall events that occurred during the warm half-year period (April to September) are first identified, with the requirement that the inter-arrival time between two subsequent events is at least 2 hours. Then, for each rainfall event, the key storm characteristics (total rainfall depth *R*, storm duration *D*, and peak 10-min intensity *I*) are derived, and the number of lightning strikes is assigned in the case the event was accompanied by lightning activity. Identification of the convective events is based on the hypothesis that thunderstorms with strong convective lifting are commonly associated with lightning strikes. In our data we found that peak rainfall intensity *I* during events accompanied by lightning is significantly higher than during those events where no lightning was observed. There are smaller differences in the distributions of event durations and rainfall totals. On this basis, we define a threshold of peak intensity *I** that differentiates between the events with and without lightning with an acceptably small probability of misclassification. This allows us to identify intense summer convective events as those where $I > I^*$ regardless of their duration or total rainfall depth. Finally, the spatial variability of *I** is examined. It suggests that threshold intensities *I** are not constant in space and vary with a strong topographic signature. In the second part of the study, the seasonal convection index according to Llasat (2001) is estimated for the threshold *I** at each station. This index gives us a measure of 'convectiveness', i.e. the total precipitation depth as a result of convective storms relative to the total precipitation depth of all summer storms. We found that the seasonal convection index increases at most of the stations in Switzerland in the period 1981-2009 and in ~20% of the cases this increase is statistically significant.

Keywords: convective precipitation, 10 minute records, independent precipitation events, lightning, convection index, trends, Switzerland.

Acknowledgements: This research project is funded by the Scientific Exchange Program (Sciex-NMS) of the Swiss Confederation Grant No. 11.034 awarded to the first author. The authors are also grateful for the support of the Slovak Research and Development Agency project APVV-0303-11.

FREQUENCY OF THE WEATHER TYPES CAUSING FLOODS IN CENTRAL EUROPE AND THE FUTURE EVOLUTION BASED ON CLIMATE MODELS

I. Bonta, Gy. Babolcsai, Z. Bihari, A. Horanyi, I. Kruzsely, M. Lakatos, P. Szabo, G. Szepszo, T. Szentimrey and K. Ujváry
Hungarian Meteorological Service, H-1024 Budapest, Hungary

Abstract: According to our investigations at the Hungarian Meteorological Service, most cases causing floods in the subbasins of Danube and Tisza rivers are mainly associated with Mediterranean cyclones (V/B cyclone) and the Cyclone center type weather situations. While between 1980 and 2005 the number of these types has been decreasing, in the last five years it has increased. The annual precipitation amount decreased in Hungary between 1901-2011, at the same time the daily precipitation intensity increased during this period. Regarding climate model forecast the two regional climate models used in Hungary "agree" in the increase of the mean temperature, at the same time the precipitation results are less clear. According to the simulation results if rainfall occurs in the future its intensity will be higher than in the past. It means that regarding increasing of the daily precipitation intensity similar signal can be observed in the past and in the future based on climate models.

Keywords: catalogue, weather types, trends, climate models, precipitation intensity.

ANALYSİS OF EXTREME RAİN AND FLOOD EVENTS USİNG A REGİONAL HYDROMETEOROLOGİCAL SYSTEM

Ismail Yucel and Alper Onen
Middle East Technichal University, Civil Engineering Department,
Water Resources Lab, 06800 Ankara Turkey
e-mail: iyucel@metu.edu.tr

Abstract: Evidence is showing that global warming or climate change has a direct influence on changes in precipitation and the hydrological cycle. Extreme weather events such as heavy rainfall and flooding are projected to become much more frequent as climate warms. Regional hydrometeorological system model which couples the atmosphere with physical and gridded based surface hydrology provide efficient predictions for extreme hydrological events. This modeling system can be used for flood forecasting and warning issues as they provide continuous monitoring of precipitation over large areas at high spatial resolution. This study examines the performance of the Weather Research and Forecasting (WRF-Hydro) model that performs the terrain, sub-terrain, and channel routing in producing streamflow from WRF-derived forcing of extreme precipitation events. The capability of the system with different options such as data assimilation is tested for number of flood events observed in basins of western Black Sea Region in Turkey. Rainfall event structures and associated flood responses are evaluated with gauge and satellite-derived precipitation and measured streamflow values. The modeling system shows skills in capturing the spatial and temporal structure of extreme rainfall events and resulted flood hydrographs. High-resolution routing modules activated in the model enhance the simulated discharges.

Keywords: flood, extreme rain, model, flood routing.

STOCHASTIC DAILY PRECIPITATION MODEL WITH A HEAVY-TAILED COMPONENT

Neyko M. Neykov and Plamen N. Neytchev
National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences,
66 Tsarigradsko chaussee, Sofia 1784, Bulgaria

Abstract: The standard methodology for development of at site daily precipitation model consists of fitting non-stationary two-state first-order Markov chain model with mixed transition density of a discrete component at zero and a continuous component describing non-zero amounts to daily precipitation amounts data. This methodology uses the generalized linear models (McCullagh and Nelder, 1989). The occurrence probability describing the discrete component is modeled by binary logistic regression whereas the intensity component describing non-zero amounts is modeled by a right skewed distribution, e.g., Gamma, Weibull, lognormal and the precipitation amount is then modeled using the joint density. It is well known that any of the above continuous distributions do not produce a heavy enough upper tail for the distribution to capture heavy precipitation intensities. To overcome this deficiency the Gamma distribution is replaced by a hybrid Gamma distribution, a Gamma distribution whose upper tail is replaced by generalized Pareto (GPD) distribution tail (Furrer and Katz, 2008). As a consequence the Gamma distribution accommodates the low and moderate precipitation values whereas the high precipitation intensities are accommodated by the GPD (Coles, 2001). Similarly, a hybrid Weibull distribution is derived and included in this study. Summary measures of the atmospheric data are incorporated as predictor variables into the precipitation intensity component by the scale and shape parameters of the hybrid distributions and by the logistic model for precipitation occurrence. The proposed downscaling approaches are applied to 30 weather stations covering broadly the territory of Bulgaria. A 47-year record (1960-2007) of daily precipitation amounts is used at each station. The atmospheric data consists of daily sea-level pressure, air temperature, geopotential height, temperature, wind components, specific and relative humidity at standard levels based on NCEP/NCAR dataset for the same period. Detailed models validation is carried out on various aspects. The results show that the downscaled simulations reproduce satisfactorily the observed precipitation probabilities, the precipitation amounts, and the wet and dry spell length distributions.

Keywords: Generalized Linear Models, precipitation, NCEP reanalysis, statistical downscaling.

APPLICATION OF A HYBRID APPROACH IN NONSTATIONARY FLOOD FREQUENCY ANALYSIS – A POLISH PERSPECTIVE

Krzysztof Kochanek[1], Witold G. Strupczewski[1], Ewa Bogdanowicz[2] and Iwona Markiewicz[1]
[(1)]Institute of Geophysics Polish Academy of Sciences, Ksiecia Janusza 64; 01-452 Warsaw, Poland
(kochanek@igf.edu.pl, wgs@igf.edu.pl, iwonamar@igf.edu.pl)
[(2)]Institute of Meteorology and Water Management, Podlesna 61, 01-673 Warsaw, Poland
(ewa.bogdanowicz@imgw.pl)

Abstract: The alleged changes in river flow regime resulted in the surge in the methods of non-stationary flood frequency analysis (NFFA). The classical approach, based on maximum likelihood estimation with the time as the covariate (descriptive value), proves to produce big errors caused by improper model assumption in estimates of time-dependent moments (unless the normal distribution is chosen) and quantiles. Moreover, the ML estimates of a number of parameters, i.e. the parameters of time-function of the distribution parameters, are unstable; difficulties increase with the number of parameters and the calculations may fail for unknown reasons. To mitigate these problems, a new two-level method of NFFA based on the concept of linear moments was developed. These two steps consists in (1) weighted least square estimation of trends in mean value and/or in standard deviation and 'de-trendisation' of the time series and (2) estimation of parameters and quantiles of the stationary sample with linear moments method and 're-trendisation' of quantiles. As a result time-dependent quantiles for a given time and return period can be calculated. Indeed, the comparative results of Monte Carlo simulations confirmed the superiority of two-step NFFA methodology over the classical maximum likelihood one if the true probability distribution function is not known. The bias and mean square error of the estimators of time-dependent quantiles are much smaller in the two-step procedure than in classical approach regardless the assumed trends or sample size. This is the result of greater robustness for wrong distributional assumption and both higher reliability and stability of the two-step methodology. Moreover, in the classical maximum likelihood approach the value and the sign (plus or minus) of the trends in first two moments depend strongly on the assumed model, whereas in two-step approach they are model independent. The capacity of the two methods developed by the Authors were compared to the operational usefulness of package Generalized Additive Models for Location, Scale and Shape (GAMLSS). Further analysis of trends in annual maxima series for Polish rivers by means of both NFFA methods revealed big differences between classical and two-step estimators of trends got for the same time-series by the same model (GEV or Gumbel). It happens, that two-step method detects positive trend whereas maximum likelihood the negative one. Surprisingly, the differences in values of time-dependent upper quantiles (F = 0.9 or 0.99) calculated within the time span covered by the time series do not exceed a few dozens of percent for GEV model (for Gumbel it is even less). Of course, the difference grows rapidly when the quantiles are calculated for the time beyond the series (e.g. when forecasting peak flows for the future). Additionally, it was noticed that quantiles estimated by the methods of traditional stationary flood frequency analysis equal only to those non-stationary calculated for a strict middle of the time series. It proves that use of traditional stationary methods in conditions of variable regime is too much a simplification and leads to erroneous results. Therefore, when the phenomenon is non-stationary, so should be the methods used for its interpretation. On the other hand the abilities to model complex non-stationary hydrological events are still very modest.

Keywords: flood frequency analysis, non-stationary, error analysis, two-level method, maximum likelihood, monte carlo simulations, linear moments.

NONSTATIONARY FREQUENCY ANALYSIS OF MAXIMUM DAILY RAINFALL USING CLIMATE COVARIATES

Lampros Vasiliades[1], Panagiota Galiatsatou[2] and Athanasios Loukas[1]
[(1)]Department of Civil Engineering, University of Thessaly, Pedion Areos, 38334 Volos, Greece
[(2)]Department of Civil Engineering, Aristotle University Thessaloniki, 54124 Thessaloniki, Greece
e-mail: lvassil@uth.gr, Fax: +30 2421074169

Abstract: Nowadays there is strong evidence that the hydroclimatic system is nonstationary on time scales that are relevant to extreme value analysis, due to natural climate variability or anthropogenic climate change. Hence, new methods are required to deal with nonstationary timeseries in hydroclimatology. In this study the generalized extreme value (GEV) distribution is used to assess nonstationarity in annual maximum daily rainfall timeseries for selected meteorological stations in Greece and Cyprus. The GEV distribution parameters are specified as functions of time-varying covariates and estimated using the conditional density network (CDN) as proposed by Cannon (2010). The CDN is a probabilistic extension of the multilayer perceptron neural network. If one of the covariates is dependent on time, then the GEV-CDN model could perform nonstationary GEV analysis. Model parameters are estimated via the generalized maximum likelihood (GML) approach using the quasi-Newton BFGS optimization algorithm, and the appropriate GEV-CDN model architecture for a selected meteorological station is selected by fitting increasingly complicated models and choosing the one that minimizes the Akaike information criterion with small sample size correction. For each meteorological station in Greece and Cyprus different formulations are tested with combinational cases of stationary and nonstationary parameters of the GEV distribution, linear and non-linear architecture of the CDN and combinations of the input climatic covariates. Climatic covariates examined in this study are the Southern Oscillation Index (SOI), which describes atmospheric circulation in the eastern tropical pacific related to El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) index, that varies on an interdecadal rather than interannual time scale and the atmospheric circulation patterns as expressed by the North Atlantic Oscillation (NAO) index.

Keywords: rainfall frequency analysis, nonstationary timeseries, generalized extreme value distribution, conditional density network, climatic covariates.

BAYESIAN METHODS FOR NON-STATIONARY FREQUENCY ANALYSIS: IMPACT OF ENSO ON MAXIMUM DAILY RAINFALL IN AUSTRALIA

Xun Sun[1], Benjamin Renard[1], Michel Lang[1] and Mark Thyer[2]
[(1)]Irstea, Hydrology-Hydraulics research unit, 3 bis quai Chauveau, 69336 Lyon cedex 09, France
[(2)]University of Adelaide, School of Civil, Environmental & Mining Engineering, Australia

Abstract: As the standard assumption of identically distributed values from the extreme value theory cannot be accepted in a non-stationary context (e. g with a changing environment), hydrologists are now developing new statistical tools. The most common approach is to introduce non-stationarity through the parameters of the extreme distribution, by using regression models linking parameter values with some time-varying covariates. Bayesian inference offers an attractive framework, allowing: 1/ to introduce expert knowledge into prior distribution, 2/ to assess posterior distribution of the parameters and the quantiles, by combining prior distribution with a sample of maximum values, 3/ to associate probabilities to several non-stationary competing models and to compute a weighted average of the different models. We present here a case study on 10 long rainfall series in Southeast Queensland, in Australia. The Bayesian framework is used to assess the parameters of a non-stationary model on summer maximum rainfall. A climatic covariate is introduced as the Southern Oscillation Index (SOI), a measure of the El Niño Southern Oscillation (ENSO). The aim is to conclude on the significance of the link between maximum daily rainfall and SOI. The application demonstrates that during the La Niña episodes, SOI has a statistically significant impact, whereas no influence is found during the El Niño episodes.

Keywords: Bayesian analysis, rainfall frequency analysis, non-stationary context, ENSO, SOI, Australia, Queensland.

REASSESSING FLOOD FREQUENCY FOR THE RIVER TRENT THROUGH THE INCLUSION OF HISTORICAL FLOOD INFORMATION SINCE AD 1320

Neil Macdonald
Department of Geography, University of Liverpool, Liverpool L69 3BX, United Kingdom

Abstract: The estimation of return periods for floods likely to have significant societal impact is challenging unless suitably long records exist. Relatively few sites across the UK provide a continuous record of river level or discharge over 50 years, whilst records extending back to the nineteenth century are rare. This represents a significant problem in providing robust and reliable estimates of flood risk, as relatively short records often fail to include an adequate sample of large floods. The inclusion of historical flood levels/magnitudes prior to instrumental river flow recording presents a valuable opportunity to extend this dataset. This paper examines the value of using historical data (both documentary and epigraphic) to augment existing gauged records for the River Trent in Central England, as part of a multi-method approach to assessing flood risk. Single station and pooled methods are compared with flood risk estimates based on an augmented historical series (1795–2008) using the generalised logistic and generalised Pareto distributions. The value of using an even longer, but less reliable, extended historical series (1320–2008) is also examined. It is recommended that modelling flood risk for return periods >100 years should incorporate historical data, where available, and that a multi-method approach increases confidence in flood risk estimates.

Keywords: flood frequency, flood risk, historical floods, generalised logistic distribution, generalised Pareto distribution, River Trent.

INVESTIGATION OF HYDROLOGICAL DESIGN PRACTICES BASED ON HISTORICAL FLOOD EVENTS IN AN EXPERIMENTAL BASIN OF GREECE (LYKOREMA, PENTELI)

Marina Mathioudaki, Andreas Efstratiadis and Nikos Mamassis
Department of Water Resources and Environmental Engineering, National Technical University of Athens, Heroon Polytechneiou 5, GR-157 80, Zographou, Greece

Abstract: Typically, the hydrological design procedure in ungauged basins comprises three computational steps: (a) the formulation of the design storm; (b) the estimation of the "effective" rainfall (direct runoff); and (c) the derivation of the flood hydrograph at the basin outlet. In particular, the most widespread approaches with regard to (b) and (c) are the Soil Conservation Service Curve Number (SCS-CN) method and the unit hydrograph (UH), respectively. The SCS-CN method extracts the effective from the total rainfall through an elementary model that uses two parameters, i.e. the curve number (CN), which determines the potential maximum soil moisture retention of the basin, and the initial abstraction, which is in general assumed as 20% of the later. Next, the effective rainfall is propagated through the UH, which is a linear response function employing the spatiotemporal transformation of the direct runoff across the basin. In the absence of flow data, synthetic UHs are employed, for which various empirical formulas exist, derived from hydrological investigations in experimental basins worldwide. Yet, the suitability of such regionalization approaches is questionable, when aiming to apply them in areas with substantially different hydroclimatic and geomorphological characteristics. This issue certainly involves small-scale Greek basins of ephemeral runoff, which are affected by relatively short yet intense storm events causing flash floods. The objective of our study is the evaluation of the aforementioned methods, on the basis of historical flood data from the experimental basin of Lykorema. The basin is located in Penteli Mountain and covers an area of 15.2 km^2. It is equipped with three meteorological stations and two flow gauges, from which we selected 35 rainfall and flood events to analyze. In all events was shown that the use of the SCS-CN method, with typical parameter values, in conjunction with two well-known synthetic UHs (Snyder and British Hydrological Institute) provided unrealistic predictions. The key reasons were the significant overestimation of both the CN value and the initial abstraction rate, as well as the improper representation of the shape of the UHs (particularly their rising branch). In this respect, we attempted to adjust the SCS-CN method, given that the CN is not a constant but a variable that actually depends on the soil moisture conditions, while the initial abstraction ratio is rather minor. In addition, we developed a synthetic parametric UH, described by a linear rising branch and a logarithmic falling branch. This uses as inputs the time of concentration, estimated by the Giandotti formula, and another duration parameter, estimated via calibration. Following a multi-criteria optimization approach, we represented with high accuracy all the important aspects of the flood hydrographs, in terms of runoff volume, magnitude and location of the peak. Although the implementation of the proposed framework in the specific basin was quite satisfactory, there is much more work to be done for establishing consistent design practices and guidelines of general use. An ultimately important step is the development of pilot basins and the collection of reliable flood data, which will allow providing much more accurate models and formulas.

Keywords: SCS-CN method, synthetic unit hydrograph, time of concentration, calibration.

FLOOD FREQUENCY ANALYSIS SUPPORTED BY THE LARGEST HISTORICAL FLOOD

Witold G. Strupczewski[1], Krzysztof Kochanek[1] and Ewa Bogdanowicz[2]
[(1)]Institute of Geophysics Polish Academy of Sciences, Ksiecia Janusza 64; 01-452 Warsaw, Poland
(wgs@igf.edu.pl, kochanek@igf.edu.pl)
[(2)]Institute of Meteorology and Water Management, Podlesna 61, 01-673 Warsaw, Poland
(ewa.bogdanowicz@imgw.pl)

Abstract: The use of nonsystematic flood data for statistical purposes depends on reliability of assessment both flood magnitudes and their return period. The earliest known extreme flood year is usually the beginning of the historical record. Even if one properly assess the magnitudes of historic floods it remains a problem of their return periods. The matter in hand is that the only largest flood (XM) is known during whole historical period and its occurrence marks the beginning of the historical period and defines its length (L). It is the common practice of using the earliest known flood year as the beginning of the record. It means that the L value selected is an empirical estimate of the lower bound on the true M. The estimation of the return period of XM based on its occurrence (L), i.e. $\hat{M} = L$, gives the severe upward bias. Problem arises to estimate the time period (*M*) representative of the largest observed flood *XM.* From the discrete uniform distribution with support 1,2,..,*M* to minimize the error of estimate of the time of its occurrence $\sum_{t=1}^{M} p_t \left(t - \hat{L}\right)^2 = \min$ where $p_t = 1/M$, one gets $\hat{L} = M/2$.Therefore $\hat{M} = 2L$ can be taken as the return period of *XM* and as the effective historical record length as well this time. If in the systematic period (N) all its elements are smaller than *XM,* one gets $\hat{M} = 2L + N$. The efficiency of using the largest historical flood (*XM*) for large quantile estimation (i.e.. one with return period $T = 100$ years) will be assessed using ML method with various length of systematic record (*N*) and various estimates of historical period length $\hat{M}$ comparing accuracy with the case when systematic records alone (N) are used only. The simulation procedure used for the purpose incorporates *N* systematic record and one largest historic flood (XM_i) in the period M which appeared in the L_i year backward from the end of historical period. The simulation result for selected distributions, values of their parameters, different *N* and *M* values are presented in terms of bias and RMSE of the quantile of interest and widely discussed.

Keywords: flood frequency analysis, historical information, error analysis, maximum likelihood, Monte Carlo simulations.

TREND ANALYSIS AND CLIMATE CHANGE PROJECTIONS OF EXTREME PRECIPITATION AND FLOOD FREQUENCY IN EUROPE – A REVIEW

H. Madsen[1], D. Lawrence[2], M. Lang[3], M. Martinkova[4] and T.R. Kjeldsen[5]
[(1)]DHI, Hørsholm, Denmark
[(2)]Norwegian Water Resources and Energy Directorate, Oslo, Norway
[(3)]Irstea, UR HHLY, Lyon, France
[(4)]T.G. Masaryk Water Research Institute, Prague, Czech Republic
[(5)]Centre for Ecology & Hydrology, Wallingford, UK

Abstract: As part of the COST Action ES0901 "European procedures for flood frequency estimation (FloodFreq)" a review of trend analysis and climate change projections of extreme precipitation and flood frequency in Europe has been conducted. Trend analyses have been reported for 21 countries in Europe with results for extreme precipitation, extreme streamflow or both. A large number of national and regional trend studies have been carried out. Most studies are based on statistical methods applied to individual time series of extreme precipitation or extreme streamflow using the non-parametric Mann-Kendall trend test or regression analysis. Some studies have been reported that use field significance or regional consistency tests to analyse trends over larger areas. Some of the studies also include analysis of trend attribution. The studies reviewed indicate that there is some evidence of a general increase in extreme precipitation, whereas there are no clear indications of significant increasing trends at regional or national level of extreme streamflow. For some smaller regions increases in extreme streamflow are reported. Several studies from regions dominated by snowmelt-induced peak flows report decreases in extreme streamflow and earlier spring snowmelt peak flows. Climate change projections have been reported for 14 countries in Europe with results for extreme precipitation, extreme streamflow or both. The review shows various approaches for producing climate projections of extreme precipitation and flood frequency based on alternative climate forcing scenarios, climate projections from available global and regional climate models, methods for statistical downscaling and bias correction, and alternative hydrological models. A large number of the reported studies are based on an ensemble modelling approach that use several climate forcing scenarios and climate model projections in order to address the uncertainty on the projections of extreme precipitation and flood frequency. Some studies also include alternative statistical downscaling and bias correction methods and hydrological modelling approaches. Most studies reviewed indicate an increase in extreme precipitation under a future climate, which is consistent with the observed trend of extreme precipitation. Hydrological projections of peak flows and flood frequency show both positive and negative changes. Large increases in peak flows are reported for some catchments with rainfall-dominated peak flows, whereas a general decrease in flood magnitude and earlier spring floods are reported for catchments with snowmelt-dominated peak flows. The latter is consistent with the observed trends. A review of existing guidelines in Europe on design floods and design rainfalls shows that only few countries explicitly address climate change. These design guidelines are based on climate change adjustment factors to be applied to current design estimates and may depend on design return period and projection horizon. The review indicates a gap between the need for considering climate change impacts in design and actual published guidelines that incorporate climate change in extreme precipitation and flood frequency. Most of the studies reported are based on frequency analysis assuming stationary conditions in a certain time window (typically 30 years) representing current and future climate. There is a need for developing more consistent non-stationary frequency analysis methods that can account for the transient nature of a changing climate.

Keywords: trend analysis, climate change, flood frequency, extreme precipitation.

FLOOD PATTERN CHANGES IN THE RIVERS OF THE BALTIC STATES

Jurate Kriauciuniene[1], Diana Sarauskiene[1] and Alvina Reihan[2]
[(1)]Laboratory of Hydrology, Lithuanian Energy Institute, Breslaujos 3, LT-44403 Kaunas, Lithuania,
e-mail: hydro@mail.lei.lt
[(2)]Institute of Environmental Engineering, Tallinn University of Technology, Ehitajate tee 5,
EE-19086 Tallinn, Estonia

Abstract: Extreme floods can be caused by different combinations of hydrological and meteorological factors and river basin conditions. Numerous hydrological data derived from water measurement stations enables us to perform direct statistical analysis of river runoff characteristics. Long-term observational series permit to estimate both the frequency and variation of spring floods that is key issue of protection systems. Changes in river floods in the Baltic States (Estonia, Latvia and Lithuania) were investigated by individual national studies. However, there are no studies of the changes of flood patterns by using a common methodology for the rivers of this region. In this study flood pattern changes in the rivers of the Baltic States were estimated using trend and frequency analysis. Spring flood parameters for the Baltic countries were assessed for four periods (1922–2010, 1931–1960, 1961–1990 and 1991–2010). We used 19 long-term hydrological data series of maximum discharges from all the Baltic countries. The Mann-Kendall test and the nonparametric Sen's method for the magnitude of the trend were used to detect trends in time series for selected periods. A comparison of 7 widely used probability distributions was performed in order to estimate the best fit distribution for the studied rivers. The results showed that maximum discharges of spring floods decreased over a longer time. Spring flood peaks took place on earlier dates. Only some significant trends of maximum discharges were found in the last time period (1991-2010). All these changes could be caused by the increasing ambient temperature and precipitation in the last decades. Generalized Extreme Value (GEV) distribution provided the best approximation to the distributions of the Baltic States rivers for the whole observation period.

Keywords: Baltic countries, spring floods, trends, distributions.

EFFECTS OF CLIMATE MODEL INTERDEPENDENCY ON THE UNCERTAINTY QUANTIFICATION OF EXTREME RAINFALL PROJECTIONS

M.A Sunyer[1], H. Madsen[2], D. Rosbjerg[1] and K. Arnbjerg-Nielsen[1]
[(1)]DTU Environment, Miljøvej building 113, DK-2800 Kgs.Lyngby, Denmark (masu@env.dtu.dk)
[(2)]DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark

Abstract: Changes in rainfall extremes under climate change conditions are subject to numerous uncertainties. One of the most important uncertainties arises from the inherent uncertainty in climate models. In recent years, many efforts have been made in creating large multi-model ensembles of both Regional Climate Models (RCMs) and General Circulation Models (GCMs). These multi-model ensembles provide the information needed to estimate probabilistic climate change projections. Several probabilistic methods have been suggested. One common assumption in most of these methods is that the climate models are independent. The effects of this assumption on the uncertainty quantification of extreme rainfall projections are addressed in this study. First, the interdependency of the 95% quantile of wet days in the ENSEMBLES RCMs is estimated. For this statistic and the region studied, the RCMs cannot be assumed independent. Then, a Bayesian approach that accounts for the interdependency of the climate models is developed in order to quantify the uncertainty. The results of the Bayesian approach show that the uncertainty is narrower when the models are considered independent. These results highlight the importance of accounting for the climate model interdependency when estimating the uncertainty of climate change projections.

Keywords: interdependency, RCM, multi-model ensemble, uncertainty, extreme rainfall, Bayesian.

REGIONAL DESIGN STORM AS RISK ESTIMATION IN FLOOD RISK ASSESSMNET OF GREECE

Nicolas R. Dalezios, Anna Blanta and Athanasios Loukas
Laboratory of Hydrology and Aquatic Systems Analysis, Department of Civil Engineering,
University of Thessaly, Volos, Greece
email: dalezios@uth.gr

Abstract: This paper deals with flood risk estimation in climatic regions of Greece, which is accomplished through regional design storm including analysis of rainfall depth, duration, frequency and their relationships in each climatic region. Climatic classification of Greece is achieved through Factor Analysis (FA) using monthly precipitation data of 37 stations over Greece for the period 1950-1981. The next step consists of the design storm through the development of depth-duration-frequency (DDF) relationships for each station and mapping of Greece. For the estimation of DDFs, daily rainfall data from 24 stations over Greece for the period 1950-1981 are used. The Extreme Value I (Gumbel) distribution has the best fit and it is fitted to the maximum annual rainfall depths for various durations. The analysis has shown that the rainfall of various durations and return periods represents a certain percentage of the mean annual precipitation for hydrologically homogeneous areas of Greece.

Keywords: flood risk estimation, design storm, rainfall depth-duration-frequency.

COMPARISON OF VARIOUS DISTRIBUTION PARAMETER ESTIMATION METHODS IN ANNUAL MAXIMUM AND PEAK OVER THRESHOLD MODELS FOR MODELLING EXTREME RAINFALL EVENT

Stavros Anastasiadis, Demetris F. Lekkas* and Georgios Liagkas
Department of Statistics and Actuarial-Financial Mathematics, Analysis and Simulation of Environmental Systems, University of the Aegean, 83200 Samos, Greece.
(*) e-mail: dlekkas@env.aegean.gr

Abstract: Modelling extreme rainfall events is essential for the design of hydraulic structures such as dam, bridges as well as for developing flood mitigation strategies. The statistical definition of Return Period (RP) or T, has been introduced for hydrological applications and is defined as the average recurrence time interval between events of a certain intensity. In the case where the events (ex. extreme rainfall) are independent, the probability of exceedance (p) remains constant and can be defined as T = 1/p. For the analysis of extreme rainfall events, two basic methodologies have been established in hydrological applications; first via the Extreme Value Theory using the Generalized Extreme Value (GEV) distribution and the second via the Peak over Threshold (PoT) using the Generalized Pareto distribution. Both, can estimate the probability of extreme events by analyzing the behavior in the tail of each distribution. In this study, Return Period estimates for 5,10,20,50,100 years are calculated and compared using different distribution parameter estimation methods; Maximum Likehood Estimator, L-moments, TL-moments. Also, in the PoT method, several graphical techniques are used and analyzed to define the range of the threshold. A methodology is proposed for optimal threshold selection by detecting a change point using Pettit Change Point Test for the shape parameter in the Pareto distribution. Daily rainfall time series (1955-2010) from several places located in the Aegean Sea and the Central Greece were provided from Hellenic Meteorological Service (Naxos, Milos, Kithira, Mitilini, Larisa) for this study.

Keywords: extreme value theory, peak over threshold, Pettit change point test, optimal threshold selection.

COMPUTATION OF HYDROGRAPHS FOR THE FLOOD EVENT OF NOVEMBER 1996 IN XANTHI, GREECE

Sophia Lalikidou and Vlassios Hrissanthou
Department of Civil Engineering, Democritus University of Thrace, 67100 Xanthi, Greece

Abstract: At the end of November 1996, an extreme flood event occurred in the wider region of Xanthi (Thrace, northeastern Greece). In order to calculate the maximum discharge during the above event in the basin of Kosynthos River (237 km^2) and in the basin of Kimmeria Torrent (35 km^2), a rainfall-runoff model, based on the software HEC-HMS, was applied to the above basins that are located near Xanthi. In concrete terms, the following submodels were applied to Kosynthos River basin: (a) Green-Ampt for the estimation of rainfall excess, (b) Soil Conservation Service for the computation of runoff hydrograph, (c) Muskingum-Cunge for the routing of the runoff hydrographs of the sub-basins to the outlet of the whole basin. Additionally, the following submodels were applied to Kimmeria Torrent basin: (a) Soil Conservation Service – Curve Number for the estimation of rainfall excess, (b) Clark for the computation of runoff hydrograph, (c) Muskingum-Cunge for the routing of the runoff hydrograph through the main stream of Kimmeria basin. At this point, it must be noted that Kosynthos River basin was divided into ten sub-basins for a more precise computation of the hydrologic processes, while Kimmeria Torrent basin was not divided into sub-basins because of the relatively small area. Observations of the flood event were not available because of the unfavourable weather conditions. An empirical estimation only of the flood event, on the basis of the hydraulic and geometric characteristics of the cross section considered, was available for Kosynthos River, so that a comparison between computational and empirical results can be made.

Keywords: flood, hydrograph, Kosynthos basin, Kimmeria basin, HEC-HMS.

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF THESSALY

FLOODFREQ COST Action ES0901
European Procedures for Flood Frequency Estimation

INFORMATION

FLOODFREQ COST Action ES0901

URL http://www.cost-floodfreq.eu/
Email:floodfreq@uth.gr

University of Thessaly

URL http://www.uth.gr/en/index.php

Address : Argonafton & Filellinon,
GR-38221 Volos, Hellas
Tel: +30 24210 74000
Email:webmaster@uth.gr

Department of Civil Engineering

URL http://www.civ.uth.gr/indexenglish.html

Address : Pedion Areos,
GR-38334 Volos, Hellas
Tel: +30.2421.074113,
Fax: +30.2421.074169

Volos Information Center

URL http://www.volosinfo.gr/en

Address : Sekeri - Lampraki,
GR-38334 Volos, Hellas
Tel: +302421 0 30930
Fax: +302421 0 30940
Email:@otenet.gr